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ABSTRACT. *Five planter configurations were evaluated for seed spacing uniformity at three field speeds using a seed location method in the field and a laboratory method involving an opto-electronic sensor system. Planter seed spacing uniformity was described using the Coefficient of Precision (CP3) measure. Results showed that CP3 measures determined using the laboratory test method were significantly different from those determined using the field test method. This indicated the laboratory test method cannot be used to predict planter seed spacing uniformity in the field. Seed spacing uniformity determined in laboratory tests was higher than, or equal to, seed spacing uniformity determined in field tests. This indicated the laboratory test method may be useful to screen out planters or planter units with poor uniformity of seed metering. Field testing of the planters that perform well in laboratory tests must be conducted to adequately determine the seed spacing uniformity of those planters in the field. Results from laboratory and field tests could be useful in determining areas for improvement of planters or planter units.*
Keywords. *Planters, Precision planters, Seed planters, Spacing, Uniformity, Sensors, Instrumentation, Monitors, Sugar beets.*

Uniform seed spacing has been demonstrated to be a significant factor in quality and yield for some crops such as sugarbeets. With uniform spacing, the roots can grow to a uniform size and fill the row space without being pushed out of the row by a neighboring root. This ensures that all of each root can be gathered from the row by the harvester. With uneven plant spacing, some roots may be too small to be gathered by the harvester, or some roots may be too large, and may be damaged by the topping implements, or the lifting wheels of the harvester (Jaggard, 1990).

Traditional methods of sugarbeet planting have involved planting excess seed and thinning the resulting plants to obtain the desired plant population at a uniform plant spacing. Until the 1970s nearly all the sugarbeet crop in the world, including the United States, was planted with excess seed and the resulting plants thinned to a final stand. Advancements in plant establishment practices such as seed bed preparation, high quality seed, and precision planters, have provided higher and more consistent seedling emergence. As a result, sugarbeets have been planted-to-stand (planted at the desired population, in contrast with planting excess seed and thinning to the desired stand population) in Western European countries such as England since the mid-1980s and the thinning operation has been eliminated (Jaggard, 1990; Prince and Durrant, 1990). Precision planters were developed in Europe to facilitate uniform spacing between plants within the row. Planter comparison studies in England have shown these precision planters have been providing accurate plant spacing for European sugarbeet producers (Thomson, 1986).

One of the differences in the evolution of plant-to-stand sugarbeets in the United States compared to Western Europe is the type of planter used for sugarbeets. General-purpose row crop planters are often preferred by many United States sugarbeet growers because of the capability to use the same planter for sugarbeet, corn, soybean, and field bean seed. Planters used for sugarbeets in England are selected on the basis of performance for emergence and spacing of sugarbeets (Smith et al., 1991b). These precision planters have been designed and selected to operate with certain size seed, and certain specialty crops.

The functions of a planter include opening a furrow, metering the seed, delivery of the seed to the furrow, covering the seed with soil, and firming the soil around the seed. Non-uniformity of seed spacing generally is related to the method of seed delivery to the furrow, and to planter travel speed (Fornstrom and Miller, 1989). The sugarbeet planter needs to be a precision machine which can singulate and place up to 12 seeds per second. If accurate results are to be achieved consistently, the planter must be tested and maintained on a regular basis.

Seed leaving the metering mechanism of a planter typically contains velocity components in the vertical direction and the horizontal direction parallel to the planter traveling direction. The horizontal velocity component results from the combination of the planter travel speed (forward), and any horizontal velocity the planter exerts on

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the seed relative to the planter (typically rearward). As the planter travel speed is usually greater than any relative horizontal velocity imparted to the seed by the planter (typically rearward), the result is a net horizontal velocity component in the direction of planter travel. This horizontal velocity gives the seed a tendency to move (e.g., bounce and roll) in the direction of planter travel upon reaching the seed furrow. This forward movement of the seed will be greatly influenced by soil conditions, and likely will vary with soil conditions, thereby affecting seed spacing uniformity. Increasing travel speed increases the potential for seed to move in the direction of planter travel, with the accompanying decrease in seed spacing uniformity.

Planter performance tests have been conducted to evaluate the distance between plants in the field, the distance between seeds on a greased belt test stand, and the distance between seeds in a furrow (Kachman and Smith, 1995; Panning, 1997; Smith et al., 1991a; Thomson, 1986). Field measurements of plant spacings can be used to evaluate a planter's seed spacing capability, but the spacing data obtained may not be a true representation of the planter's performance. Plant spacing data includes effects from plant emergence efficiency as well as effects from planter performance. Measurements of seed spacings in the furrow requires considerable time to carefully uncover all the seeds in the furrow without accidentally moving them in the uncovering process.

Planter performance factors include variability around the target drop points (drop error), failure of a seed to be dropped, multiple seeds dropped at the same time, seed bounce and roll in the furrow, and movement of the seeds as they are covered with soil. The distance between seeds for the greased belt test stand is influenced by the first three of these factors, as seed bounce and roll can be minimized by the grease on the belt, and seed movement during covering, and plant factors such as emergence and volunteer plants are not a part of the greased belt test. However, at high belt speeds, seeds may slide on a greased belt causing small errors in seed spacing measurements.

A recent development in determining planter performance involved the use of an opto-electronic seed spacing evaluation system designed and built at the University of Nebraska-Lincoln (Kocher et al., 1997; Lan et al., 1999). The opto-electronic sensor system used the measured time interval between seed drops and front-to-back location where each seed dropped through the sensor to determine seed spacing. Results indicated that seed spacing measurements obtained using the opto-electronic system were strongly correlated (average r = 0.951 from Kocher et al., 1997; $r^2 = 0.977$ from Lan et al., 1999) with the same seed spacing measurements obtained using a greased belt test stand. Unlike the greased belt test stand and the manual measurement of plant spacings in the field, the opto-electronic sensor system can be used to quickly obtain a measure of planter seed spacing performance.

Research has resulted in a wide variety of measures to quantify planter performance with regard to plant spacing. Hofman (1988) developed a seed spacing index for comparison of planter seed spacing uniformity with sunflower seed on a greased belt test stand. Jasa and Dickey (1982) also developed a seed spacing index for comparison of planter seed spacing uniformity. Brooks and Church (1987), Hollewell (1982), and Thomson (1986) examined the variability in plant spacing through the use of histograms of distances between plants. Kachman and Smith (1995) compared alternative measures such as the mean, standard deviation, quality of feed index, multiples index, miss index, and precision. They concluded that measurements based on theoretical spacing (multiples index, miss index, quality of feed index, and precision) appeared to do well in summarizing distributions of plant spacing for single seed planters, while the sample mean and sample standard deviation were not appropriate. Smith et al. (1991a) proposed the use of a new parameter for plant spacing comparisons. This parameter termed *3-cm (1.2-in.) mode range* was determined to be a better representation of the ability of a planter to space seeds or plants near the true planter spacing setting, than using the combination of average spacing and standard deviation. The 3-cm (1.2-in.) mode range provides easier visualization for comparison of planters than other measures. Other researchers have also used the 3-cm (1.2-in.) mode range as a measure for evaluating planter performance (L'Institut Technique Français de la Betterave Industrielle, 1994). They termed the measure as the Coefficient of Precision (CP3).

An example illustrates how the CP3 works to handle skips, multiples, and normal spacings. Consider a planter set to space seeds at 20.0 cm (7.87 in.) intervals, that during testing places 10 seeds at locations 0 cm (0 in.), 0.9 cm (0.35 in.), 21.3 cm (8.39 in.), 60.5 cm (23.82 in.), 79.8 cm (31.42 in.), 100.2 cm (39.45 in.), 120.7 cm (47.52 in.), 122.1 cm (48.07 in), 122.8 cm (48.35 in.), and 141.4 cm (55.67 in.) along a row. The spacings between the seeds are 0.9 cm (0.35 in.), 20.4 cm (8.03 in.), 39.2 cm (15.43 in.), 19.3 cm (7.60 in.), 20.4 cm (8.03 in.), 20.5 cm (8.07 in.), 1.4 cm (0.55 in.), 0.7 cm (0.28 in.), and 18.6 cm (7.32 in.), respectively. This indicates that the first two seeds were a double, a seed was missed between the third and fourth seed, seeds seven, eight and nine were a triple, and all the other seeds were planted normally. The CP3 would include only the spacings that were within ±1.5 cm (±0.59 in.) of the theoretical spacing of 20.0 cm (7.87 in.), so spacings within the range of 18.5 cm (7.28 in.) to 21.5 cm (8.46 in.) would be counted in the CP3. In this example, five of the nine spacings are within this range, so the CP3 value would be 55.5.

Only a few published studies have compared in-row seed spacing performance of general purpose sugarbeet planters used in the United States and specialty sugarbeet planters used in Western Europe. Giles et al. (1989) placed one European sugarbeet planter and three United States manufactured sugarbeet planters over a greased belt in 1987 tests. Among the measures they determined, the ones most closely related to seed spacing uniformity were seeding percentage, percentage of skips, and percentage of doubles. The planters were operated at 4.8, 6.4, and 8.0 km/h (3.0, 4.0, and 5.0 mph) with target seed spacings of 6.4 and 12.7 cm (2.5 and 5.0 in.). The basis used for the percentages was the theoretical number of seeds that should have been on the same length of greased belt at that target seed spacing. The seeding percentage was calculated using the actual number of seeds on the belt. The percentage of skips was calculated using the number of times spacings between consecutive seeds were at least

10.2 cm (4.0 in.) and 20.3 cm (8.0 in) for the 6.4-cm (2.5-in.) and 12.7-cm (5.0-in.) target spacings, respectively. The percentage of doubles was calculated using the number of times two or more seeds had been deposited within 2.5 cm (1.0 in.) and 5.1 cm (2.0 in.) for the 6.4-cm (2.5-in.) and 12.7-cm (5.0-in.) target spacings, respectively. Significant decreases in seeding percentages were noted for all planters as speed increased. The percentage of skips increased significantly as speed increased for the 6.4-cm (2.5-in.) target seed spacing, but not at the 12.7-cm (5.0-in.) target spacing. The explanation given for this was that the seed plate traveled half as fast at the 12.7-cm (5.0-in.) target spacing as at the 6.4-cm (2.5-in.) target spacing, so there was more time for the seed cells to fill properly at the 12.7-cm (5.0-in.) target spacing. For two of the planters (John Deere 71 Flexi-Planter and Milton planter), the doubles percentage increased with travel speed at the 6.4-cm (2.5-in.) target spacing, but did not increase at the 12.7-cm (5.0-in.) target spacing. No change in percentage of doubles was detected as the speed increased for the other two planters (Heath and Nodet Gougis) at either target seed spacing. Giles et al. (1989) concluded that seed spacing uniformity on a greased belt test stand decreased as planter speed increased for all the planters they tested.

Seed spacing uniformity is an important factor in selecting a planter for use in a plant-to-stand method of sugarbeet plant establishment. The ability of a planter to accurately distribute seeds has been tested using laboratory methods involving the greased belt test stand and field methods involving the planting of seeds and determining the spacing of the plants that have emerged. Efforts to establish the effectiveness of using laboratory results to predict field results have been minimal. Producers want to know if their planters are in condition to meet their performance expectations in the field. As a result there is considerable interest in laboratory testing which can be used to predict planter performance in the field.

Objectives

The specific objectives of this study were to:

- Compare sugarbeet seed spacing uniformity of two general purpose U.S. planters and a European specialty planter.
- Evaluate the effectiveness of laboratory planter testing methods for predicting seed spacing uniformity in the field.

Procedure

Five planter configurations were compared for accuracy of spacing between seeds within the row in a field study and a laboratory study at the University of Nebraska Panhandle Research and Extension Center near Scottsbluff, Nebraska, in 1996. Each planter was operated at three travel speeds in the field and in the laboratory.

Seed

The sugarbeet seed used was the standard size [3.7- to 4.5-mm (0.15- to 0.18-in.)-diameter] regular pelleted seed. The base sugarbeet seed was Monohikari variety.

Planters

The United States-manufactured planters used in this study have been the most commonly used ones for sugarbeets in western Nebraska in the mid 1990s. The seed metering systems of the planters can be described as follows:

Franz Kleine Unicorn-3: This planter is a European-built precision planter designed for shallow planting of small seeds such as sugarbeets. Its seed metering device consists of a seven-cell wheel designed to operate in a vertical plane and singulate seed. The seed is selected and enclosed within a small slot in the metering wheel. Once selected, the seed follows an enclosed path to eliminate the possibility of the seed leaving the metering wheel until being dispersed into the seed furrow.

John Deere 71 Flexi-Planter with Seed Plate No. B12-160R2: This planter is a general purpose planter designed for row crops such as corn and soybeans, and adapted for sugarbeets. The seed plate used was a 36-cell plate used for small seed crops such as sugarbeets. The metering plate operates in a horizontal plane at the bottom of the seed hopper. As the seed plate rotates, a seed drops into a cell and is transported to the seed tube. Upon reaching the seed tube area, the seed is allowed to fall out of the cell into the seed tube. A small spiked wheel rotating above the seed plate ensures that the seed and any small fragments of seed or coating are removed from the seed plate.

John Deere MaxEmerge® 2 (Vacuum Metering) with Seed Plate No. A51713: This planter is a general purpose planter designed for row crops such as corn and soybeans, and adapted for use with sugarbeet seed. A 45-cell seed plate was used in the metering mechanism. The seed plate operates in a vertical plane and requires a vacuum of 10 to 11 cm (4.0 to 4.5 in.) of water to select a seed. Once selected in the seed plate, the seed follows a designed path until reaching the seed tube. Once the seed reaches the location where it is to be released, the vacuum is removed and the seed is allowed to fall out of the cell. A small spiked wheel rotating on the back side of the plate ensures that the seed and any small fragments of seed or coating are removed from the seed plate.

The Franz Kleine Unicorn-3 planter had no seed tube and the John Deere 71 Flexi-Planter had a straight seed tube. The John Deere MaxEmerge 2 planter was evaluated using three different seed tube designs: a prescribed sugarbeet tube (John Deere part No. AA 38800), a custom-made straight metal tube designed for experimental purposes, and a tube assembly consisting of an outer tube (John Deere part No. BA 25839) and a tube insert (John Deere part No. AH 131883).

The custom-designed metal tube had a top shape similar to the standard John Deere tube but with straight side walls tapering to a rectangular bottom opening of 1 cm (0.4 in.) wide and 0.6 cm (0.2 in.) front-to-back. Smith (1993) had obtained very uniform seed spacing with the custom-made metal tube during planter testing in the laboratory with a greased belt at a belt (simulated travel) speed of 3.2 km/h (2.0 mph).

The seed tube assembly consisted of a seed tube used for planting corn, with a smaller insert tube that reduced the area inside the seed tube. This type of seed tube was designed to produce better depth control of the sugarbeet seed than using the outer seed tube alone.

All planter seed metering systems were adjusted for a target seed spacing of 15 cm (6.0 in.) apart within the row, and a target seed depth of 3 cm (1.2 in.). It was not a goal of this study to compare target seed spacing with actual spacing. The mode spacing was assumed to be the true spacing setting of the planter, rather than a predetermined target spacing limited by the ability of the operator to set the planter for that target setting, or limited by available planter adjustments or components. The seed spacing setting for each planter was chosen on the basis of available components and adjustments. Planter components such as seed tubes, press wheels, seed runners, etc., were selected according to the operator's manuals and local practice for sugarbeet planting.

Each planter was operated at three travel speeds (3.2, 5.6, 8.0 km/h; 2.0, 3.5, 5.0 mph) to determine the influence of speed on seed spacing. This range of travel speeds included the slow speed recommended for best seed spacing uniformity, through the high speed producers prefer to use.

Field Study

The experimental design was a split plot design with whole plots arranged in randomized complete blocks with three replications. Seed spacing was the dependent variable with the treatments being planter type and field speed. Planter type was the main plot treatment factor, and travel speed was the sub plot treatment factor. The field layout consisted of rectangular plots 24.5 m (80 ft) long × 18 m (60 ft) wide with borders of 8 m (25 ft) on each end. The planters were brought up to the selected travel speed in the border areas so the metering system was operating at the desired speed level within the plot area for each test. Within each block the operations for each planter were completed before switching to the next planter. The plot was arranged using two rows from each planter spaced 56 cm (22 in.) apart with only one row containing seed.

Field spacing measurements were obtained after each block was completely planted. Soil was carefully removed from above the seed with a putty knife or an ice scraper. By using short shallow strokes perpendicular to the row direction, the seed could be located without appreciable disturbance. Once the seed was located, a toothpick was placed beside the sugarbeet seed without disturbing the seed. Seed spacings were then measured electronically using the Plant Spacing Measurement Buggy (Panning, 1997).

Laboratory Study

The laboratory tests involved the use of the opto-electronic sensor system (Kocher et al., 1997) to determine planter seed spacing performance using the same planter configurations as in the field study. A planter row unit was mounted on a greased belt test stand which utilized an adjustable speed drive mechanism to operate the seed metering devices at a known constant speed. The sensor system was mounted under the seed tube at a position simulating the seed furrow bottom. Each test run consisted of starting the test stand drive mechanism and letting it run for about 10 s to allow the seed plate cells to fill, and the planter to run at the desired operating speed. After this start-up time, the computer operator signaled the computer to begin collecting the seed spacing data. When the computer had collected the number of seed spacings requested by the operator, the planter and greased belt test stand were turned off. The computer system then displayed the planter performance results along with a histogram of the seed spacing distribution. This process was repeated three times for a total of 450 seed spacings per field speed. Because of the time and effort involved in changing the planter row units on the test stand, each planter was evaluated at each of the three travel speeds before changing the planter row unit.

Method of Comparing Seed Spacing Performance Among Treatments

The parameter Coefficient of Precision (CP3) was used to measure and compare seed spacing performance. The CP3 is the percentage of spacings that were within a 3 cm (1.2 in.) range centered about the mode (L'Institut Technique Français de la Betterave Industrielle, 1994; Smith et al., 1991a). Higher CP3 values represent higher uniformity of seed spacings near the mode. The CP3 measure is a representation of the ability of a planter to space seeds near the true planter spacing setting. Centering the range on the mode rather than the target spacing helps remove the bias of operator adjustment or available planter components or settings (Smith et al., 1991a). No attempt was made to compare the parameters of average spacing or mode spacing, because both were dependent on the ability of the operator to prepare the planter, and not exclusively on the capability of the planters.

The CP3 is a parameter that can be understood by the sugarbeet grower for planter seed spacing performance comparisons. While the CP3 rating allows for easy interpretation of planter seed spacing performance, it may not provide all the information needed when evaluating planters. Frequency histograms which display the frequency of occurrence, in percent of each spacing increment, provide a complete picture of spacing performance and were also used in this study. These histograms presented information concerning doubles, skips, mode or actual planter setting, and uniformity (or randomness) of spacing.

Results and Discussion

Comparison of Seed Spacing Performance Among Treatments

The analysis of variance (table 1) showed there were significant differences ($p = 0.01$) in seed spacing uniformity results depending on the test method (lab versus field). There were also highly significant differences in seed spacing uniformity among the different planters, and among the different travel speeds. The interaction of test method, planter type, and travel speed was also significant. This indicates that the laboratory test method cannot be used to predict field test method results. It also indicates that each of the treatment factors of planter type and travel speed had major effects on the seed spacing uniformity results. In addition, the effects of the test method and individual treatment factors (planter type and travel speed) on seed spacing uniformity changed somewhat with

Table 1. ANOVA table for Coefficient of Precision (CP3) rating of seed spacing uniformity with two test methods (lab versus field) and treatment factors of planter type and travel speed

Source	DF	Mean Square	F Value	PR > F
Test method	1	4299	235.62	0.0001
Block(method)	4	18		
Planter type	4	5019	257.84	0.0001
Method*Planter	4	430	22.11	0.0001
Block*Planter(method)	16	20		
Travel speed	2	3589	210	0.0001
Method *Travel speed	2	5	0.27	0.7678
Travel Speed*Planter	8	118	6.91	0.0001
Method*Speed*Planter	8	63	3.68	0.0027
Error	40	17		

different combinations of test method, planter type, and travel speed.

The seed spacing uniformity results (means of CP3 values) for each of the treatment combinations are shown in table 2. Also given in table 2 are the least significant differences (LSD) appropriate for making comparisons between planter types at any speed, and between travel speeds within the same planter type.

Field Study Travel Speed Evaluation

As can be seen from the field study results in table 2, the highest seed spacing uniformities (CP3 values) for each planter were obtained at the lowest speed (3.2 km/h, 2.0 mph). In all cases, as the travel speed increased from 3.2 km/h (2.0 mph) to 8.0 km/h (5.0 mph), seed spacing uniformity decreased. The Franz Kleine Unicorn-3 planter demonstrated the smallest decrease in seed spacing uniformity with an increase of travel speed. The CP3 rating shows that the Franz Kleine Unicorn-3 planter operated in the field at a travel speed of 8.0 km/h (5.0 mph) still placed 60% of the seeds sown within a range of 3 cm (1.2 in.) about the mode seed spacing.

Laboratory Study Results

The opto-electronic sensor system used in the laboratory testing method allowed planter performance characteristics to be obtained quickly and with less variation than the field testing method. However, planter seed spacing results from either the opto-electronic sensor system or greased belt systems do not include effects of planter bounce or seed movement from bounce and roll in the furrow or while being covered with soil. Therefore, neither the opto-electronic system, nor the greased belt systems can fully predict the capability of planters to space seeds uniformly in the field.

Results in table 2 show that the laboratory method indicated seed spacing uniformity decreased as travel speed increased for every planter. However, the small decrease in seed spacing uniformity with increasing travel speed for the Franz Kleine Unicorn-3 was not significant. The trend of decreasing seed spacing uniformity with increasing travel speed also occurred in the results from the field method, so the laboratory method successfully predicted that trend.

Predicting Field Performance

The CP3 values from the laboratory method for each planter by speed combination were higher than the CP3 values obtained from the field method, except for the John Deere MaxEmerge 2 planter with the sugarbeet tube at the 3.2 and 5.6 km/h (2.0 and 3.5 mph) travel speeds. The CP3 values from the laboratory method in those two cases, however, were quite close to the CP3 values obtained from the field method. In general, the CP3 values obtained from the laboratory method were approximately equal to, or higher than the CP3 values obtained from the field method. In summary, it can be noted that if the laboratory testing method showed poor spacing uniformity for a planter by speed combination, the field results were in agreement.

This indicates that laboratory testing with the opto-electronic sensor system (or a greased belt system) could be used as a screening test to determine which planters or planter units have poor seed spacing uniformity, and therefore are not ready to be included in field tests. Planters or planter units giving good seed spacing uniformity in laboratory tests must be tested in the field to determine which ones give acceptable seed spacing results when

Table 2. Mean Coefficient of Precision (CP3) rating for seed spacing uniformity for each planter at each travel speed as measured using the field test method and the laboratory test method, along with the least significant differences (LSD)* for comparisons

	Field Method			Laboratory Method		
Planter Type	3.2 km/h (2.0 mph)	5.6 km/h (3.5 mph)	8.0 km/h (5.0 mph)	3.2 km/h (2.0 mph)	5.6 km/h (3.5 mph)	8.0 km/h (5.0 mph)
Franz Kleine Unicorn-3	74.7	68.4	60.4	80.3	78.5	77.6
John Deere MaxEmerge 2, metal seed tube	54.9	40.8	36.3	83.2	68.3	55.6
John Deere MaxEmerge 2, sugarbeet seed tube	56.4	43.6	22.7	51.7	40.3	30.9
John Deere MaxEmerge 2, insert seed tube	35.4	27.2	18.7	63.0	45.6	36.5
John Deere 71 Flexi-Planter	40.4	21.7	17.1	56.8	33.9	22.9

* LSD ($_{0.05}$) = 8.2 for field study, 6.0 for laboratory study, for comparing means between two planters at the same travel speed, or at different levels of travel speed. LSD ($_{0.05}$) = 8.2 for field study, 5.6 for laboratory study, for comparing means between any two travel speeds within the same planter.

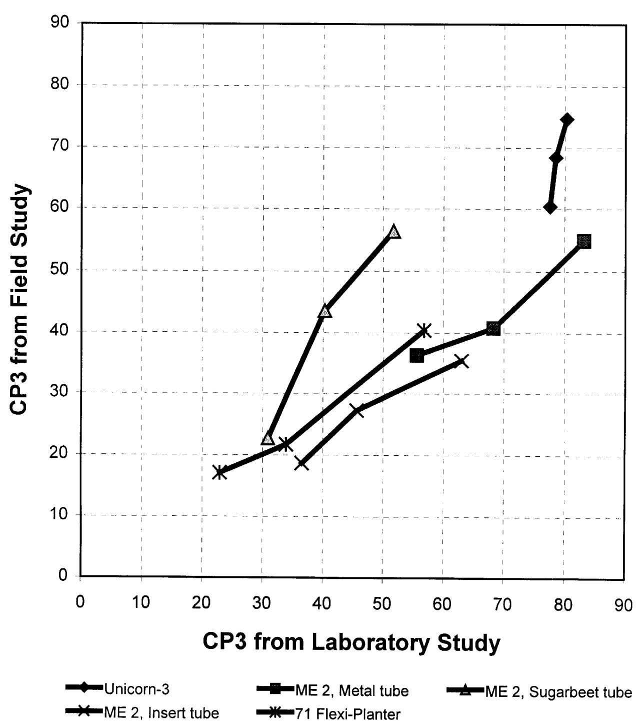

Figure 1–Scatter plot showing the comparison between the Coefficient of Precision (CP3) rating for seed spacing uniformity determined from the laboratory study and from the field study.

including the additional planter performance factors in field tests. Figure 1 illustrates the comparison between results from the field and laboratory tests.

The planters with CP3 values above 60 for at least two travel speeds in the laboratory study were the Franz Kleine Unicorn-3 and the John Deere MaxEmerge 2 with the metal experimental tube (fig. 1). The John Deere MaxEmerge 2 planter with the metal tube at the 3.2 km/h (2.0 mph) travel speed and the Franz Kleine Unicorn-3 had the highest CP3 values in the laboratory tests. From the field tests, the Franz Kleine Unicorn-3 at each of the three travel speeds had higher CP3 values than the John Deere MaxEmerge 2 with the metal tube. Relying on the laboratory test alone would have resulted in the conclusion that the John Deere MaxEmerge 2 planter with the metal tube at a travel speed of 3.2 km/h (2.0 mph) and the Franz Kleine Unicorn-3 had the highest seed spacing uniformity. The addition of the field testing, after the laboratory screening test showed that in the field, the Franz Kleine Unicorn-3 planter at travel speeds of 3.2 and 5.6 km/h (2.0 and 3.5 mph) had higher seed spacing uniformity than the John Deere MaxEmerge 2 planter with the metal tube at any travel speed.

Evaluation for Planter Improvement

The results of these tests suggest that laboratory testing with the opto-electronic sensor system (or a greased belt system), along with field testing could be useful in determining areas for improvement of planters. High CP3 values from laboratory tests indicate the planter metering system is doing well singulating seed and dropping it uniformly. The John Deere MaxEmerge 2 planter with the metal tube at a travel speed of 3.2 km/h (2.0 mph) had as high a CP3 value, or did as good a job of seed metering, as the Franz Kleine Unicorn-3 in the laboratory tests. As travel speed increased, the CP3 values for the Franz Kleine Unicorn-3 did not change significantly, while the CP3 values for the other planters decreased. This indicates the Franz Kleine Unicorn-3 seed metering system worked well at the three travel speeds used in these tests.

Planters with high CP3 values from laboratory tests and low CP3 values from field tests indicate problems controlling seed movement from bounce and roll in the furrow or while being covered with soil. The John Deere MaxEmerge 2 planter with the experimental custom metal seed tube at a travel speed of 3.2 km/h (2.0 mph) had a high CP3 value (83.2) from the laboratory tests, and a lower CP3 value (54.9) from the field tests. While this planter configuration singulated and dropped seeds uniformly, the seeds did not stay as uniformly spaced after any seed movement from bounce and roll in the furrow or while being covered with soil. These examples illustrate use of the laboratory and field test results to determine areas for improvement of planters or planter units.

Conclusions

Field testing showed the Franz Kleine Unicorn-3, a specialty planter designed for precision planting, had Coefficient of Precision ratings (CP3 values) of 75, 68, and 60 at speeds of 3.2, 5.6, and 8.0 km/h (2.0, 3.5, and 5.0 mph), respectively. In comparison, the John Deere MaxEmerge 2 planter with the sugarbeet tube, (with the best seed spacing uniformity performance of the U.S. general purpose planter configurations included in this study) had CP3 values in field tests of about 56, 44, and 23 at the same respective speeds. The older general purpose planter design, the John Deere 71 Flexi-Planter, had CP3 values in the field tests of about 40, 22, and 17 at the same respective speeds.

As laboratory testing with the opto-electronic sensor (or a greased belt) system does not account for planter bounce or seed movement from bounce and roll in the furrow and while being covered by soil, it did not adequately predict seed spacing uniformity of planters in the field. Results showed that CP3 measures determined using the laboratory test method were significantly different from those determined using the field test method. This indicated the laboratory test method cannot be used to predict planter seed spacing uniformity in the field. Seed spacing uniformity determined in laboratory tests was higher than, or equal to, seed spacing uniformity determined in field tests. This indicated the laboratory test method may be useful to screen out planters or planter units with poor uniformity of seed metering. Field testing of planters that perform well in laboratory tests must be conducted to adequately determine the seed spacing uniformity of those planters in the field. Results from laboratory and field tests could be useful in determining areas for improvement of planters or planter units.

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